An overview of the humidity package in LAPS

A review of the salient details of the evolution of this module and how it works

Dan Birkenheuer

October 2010

The fundamental components

- Referenced
- Novel application of satellite data with an emphasis on satellite data (background of the developer)
- Cloud humidification now being revisited – disabled after HMT 09
- Effort going to STMAS

Major elements in the processing

- Background field used as a-priori guess (forecast model output valid at current time)
- Surface mixing (tied to sfc dewpoints boundary layer)
- 3-level 2-dvar minimization (detailed later)
  - Sfc, clouds, gps, satellite, raob

How to deal with satellite bias?

- Two approaches
  - Perform some type of bias correction
  - Use variational methods to only rely on gradients in GOES data, relying on ancillary data for vapor amount.
- Third approach not initially evident
  - Possibly address the problem by improving the retrieval algorithm (working on this now Ma to Li algorithm)

Variational Algorithm

- The original way we used GOES product data in analysis was to analyze actual values

- It was an easy matter to modify the variational algorithm to utilize gradients in the product field, thereby ignoring bias.

- I.e., the derivative of constant bias = zero

Zero-Dimensional Variational Problem

Given the following data what is the best temperature analysis for the location?

Table 1: Thermal Data for One Station Location

Instrument	Measurement	Error
Thermometer A	284.3 K	0.5 K
Thermometer B	285.7 K	1.5 K
Satellite Radiance	87.38 (r)	0.31 (r)

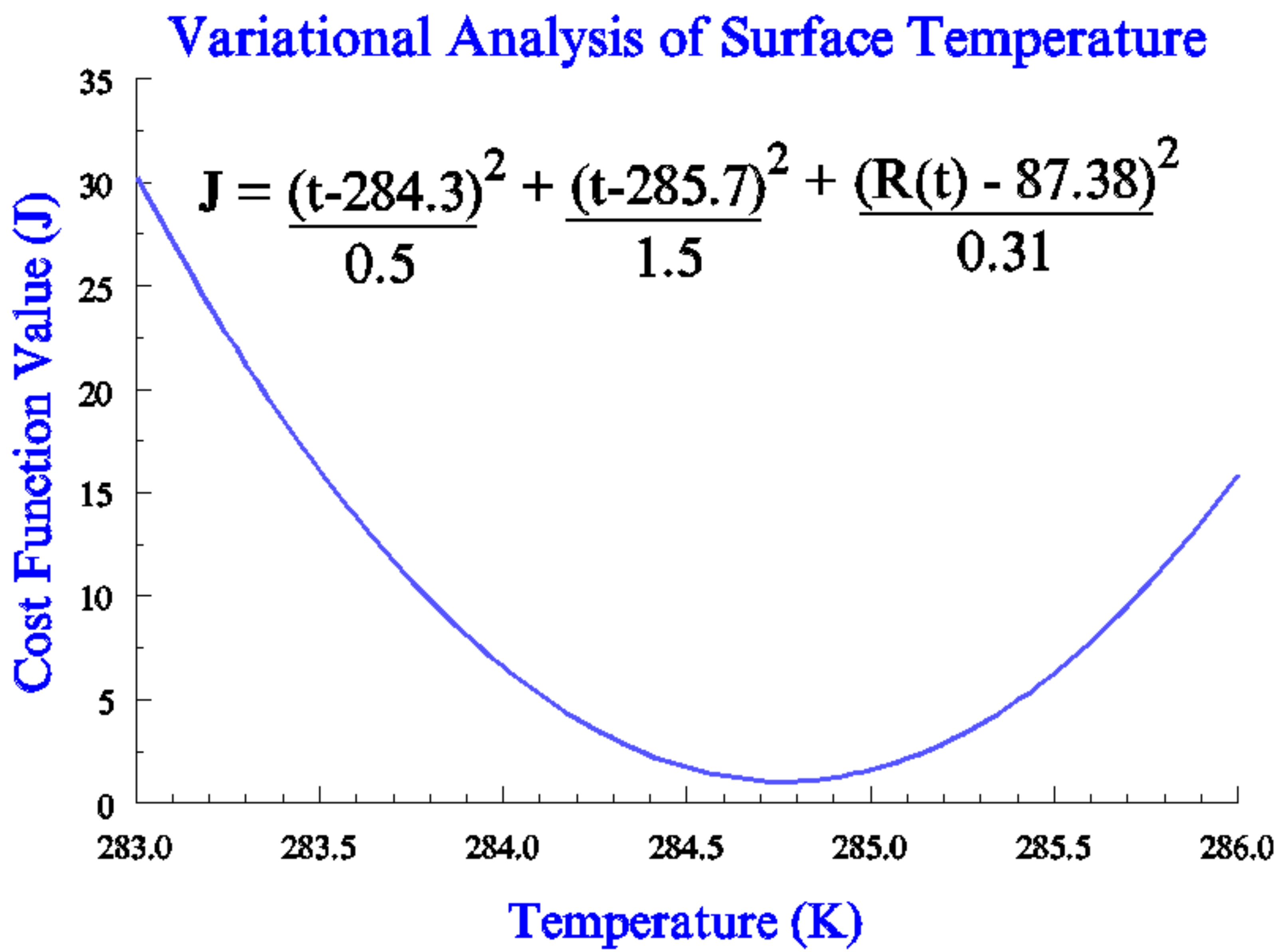
use the variational approach by minimizing the functional:

$$J_{.} = \sum \frac{(t - t_o)^2}{\sigma} + \sum \frac{(R(t) - R_o)^2}{\sigma}$$

Planck's Equation is the Forward Model R(t)¶

¶

$$R(t) = \frac{9712.319}{\left[e^{\left(\frac{1344.22}{t}\right)} - 1 \right]}$$


Variational Analysis of Surface Temperature
$J = \frac{(t-284.3)^2}{0.5} + \frac{(t-285.7)^2}{1.5} + \frac{(R(t) - 87.38)^2}{0.31}$
Cost Function Value (J)
35
30
25
20
15
10
5
0
283.0
283.5
284.0
284.5
285.0
285.5
286.0
Temperature (K)

Calculus Solution (Minimize the functional):¶

¶
¶

$$\frac{dJ}{dt} = 0 = \frac{d}{dt}\left[\Sigma\frac{(t - t_O)^2}{\sigma} + \Sigma\frac{(R(t) - R_O)^2}{\sigma}\right]$$

¶
¶
¶
¶

***t* = 284.75955 K** §

$$J = S_{SAT}\sum_{k=1}^{7}\frac{\mathrm{GT}(g_i)[\mathrm{R}(T,cq,o_3)_i - R_i^o]^2}{E_{SAT}^2} + \sum_{i=1}^{N}\frac{(1-c_i)^2}{E_{BACK}^2}$$

$$+ S_{GPS}\frac{\left(\sum_{i=1}^{N} c_i q_i - Q^{GPS}\right)^2}{E_{GPS}^2 L_{GPS}} + S_{sonde}\frac{\sum_{i=1}^{N}\left[\mathrm{RH}\left(T,p,cq\right)_i - RH_i^o\right]^2}{E_{sonde}^2 L_{sonde}}$$

$$+ S_{GVAP}\sum_{j=1}^{3}\frac{\mathrm{G}(g)[\sum_{i=1}^{N}\mathrm{P}_{ji}(c_i q_i) - Q_j^{GVAP}]^2}{E_{GVAP_j}^2 L_{GVAP}} + S_{CLD}\sum_{i=1}^{N}\frac{\mathrm{g}_i[c_i q_i - q_s(t_i)]^2}{E_{CLD}^2}$$

Original variational minimization functional, each term is a data source.

$$J = S_{SAT} \sum_{k=1}^{7} \frac{\mathrm{GT}(g_i)[\mathrm{R}(T, cq, o_3)_i - R_i^o]^2}{E_{SAT}^2} + \sum_{i=1}^{N} \frac{(1-c_i)^2}{E_{BACK}^2}$$

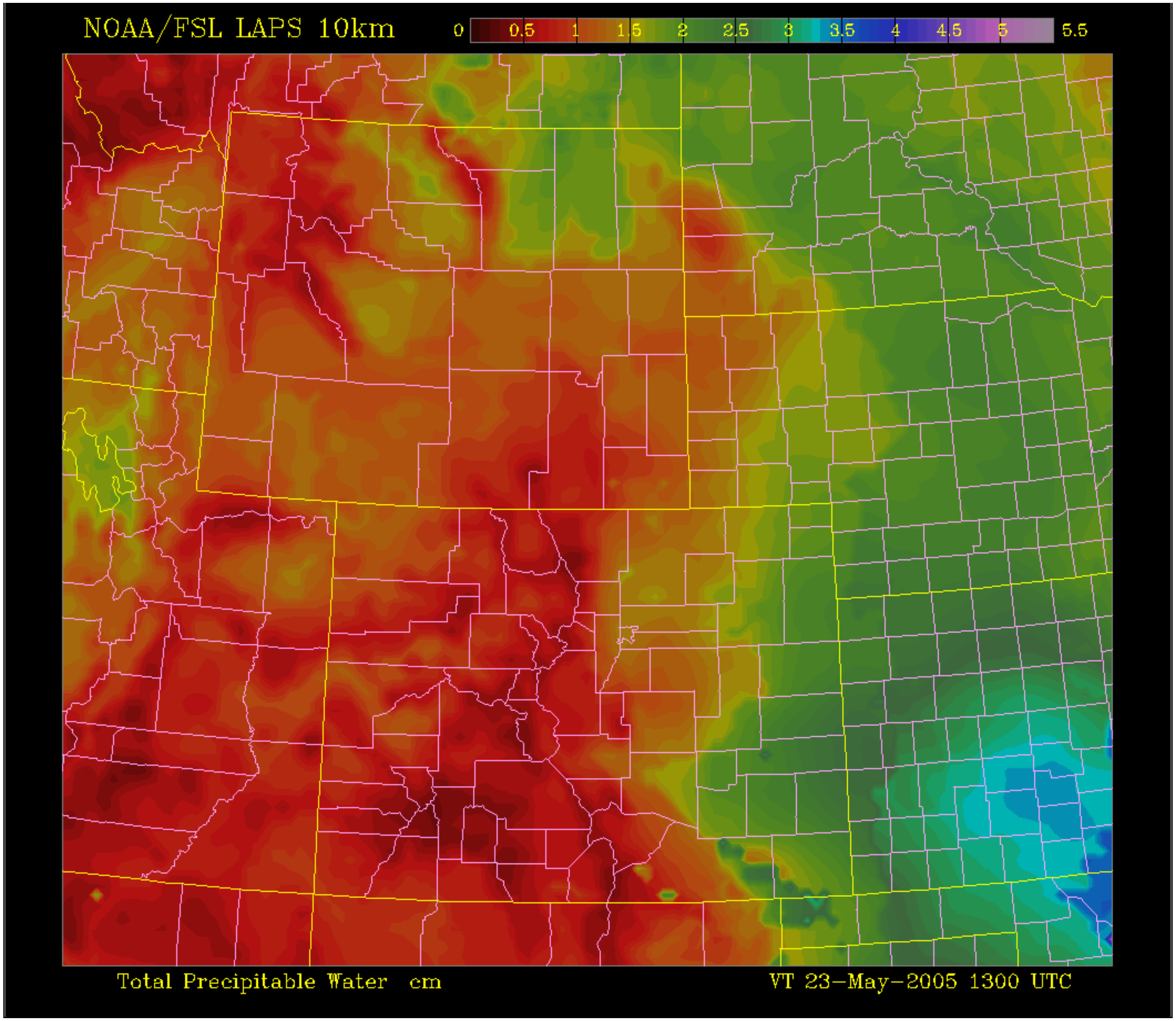
$$+ S_{GPS} \frac{\left(\sum_{i=1}^{N} c_i q_i - Q^{GPS}\right)^2}{E_{GPS}^2 L_{GPS}} + S_{sonde} \frac{\sum_{i=1}^{N} \left[\mathrm{RH}\left(T, p, cq\right)_i - RH_i^o\right]^2}{E_{sonde}^2 L_{sonde}}$$

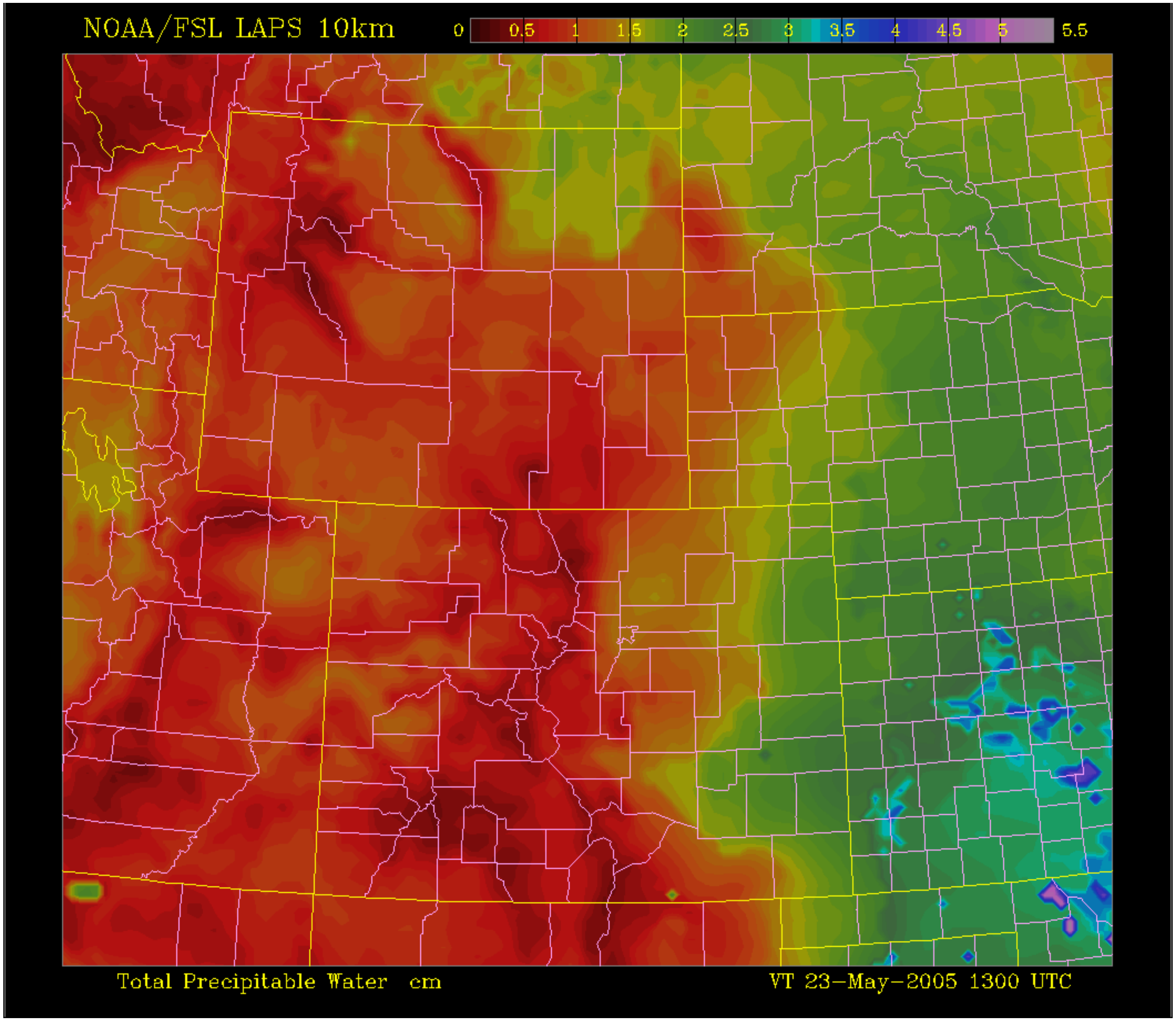
$$+ S_d S_{GVAP} \sum_{j=1}^{3} \frac{\mathrm{G}(g)[\sum_{i=1}^{N} \frac{\Delta}{\Delta x} \mathrm{P}_{ji}(c_i q_i) - \frac{\Delta}{\Delta x} Q_j^{GVAP}]^2}{E_{xGVAP_j}^2 L_{GVAP}}$$

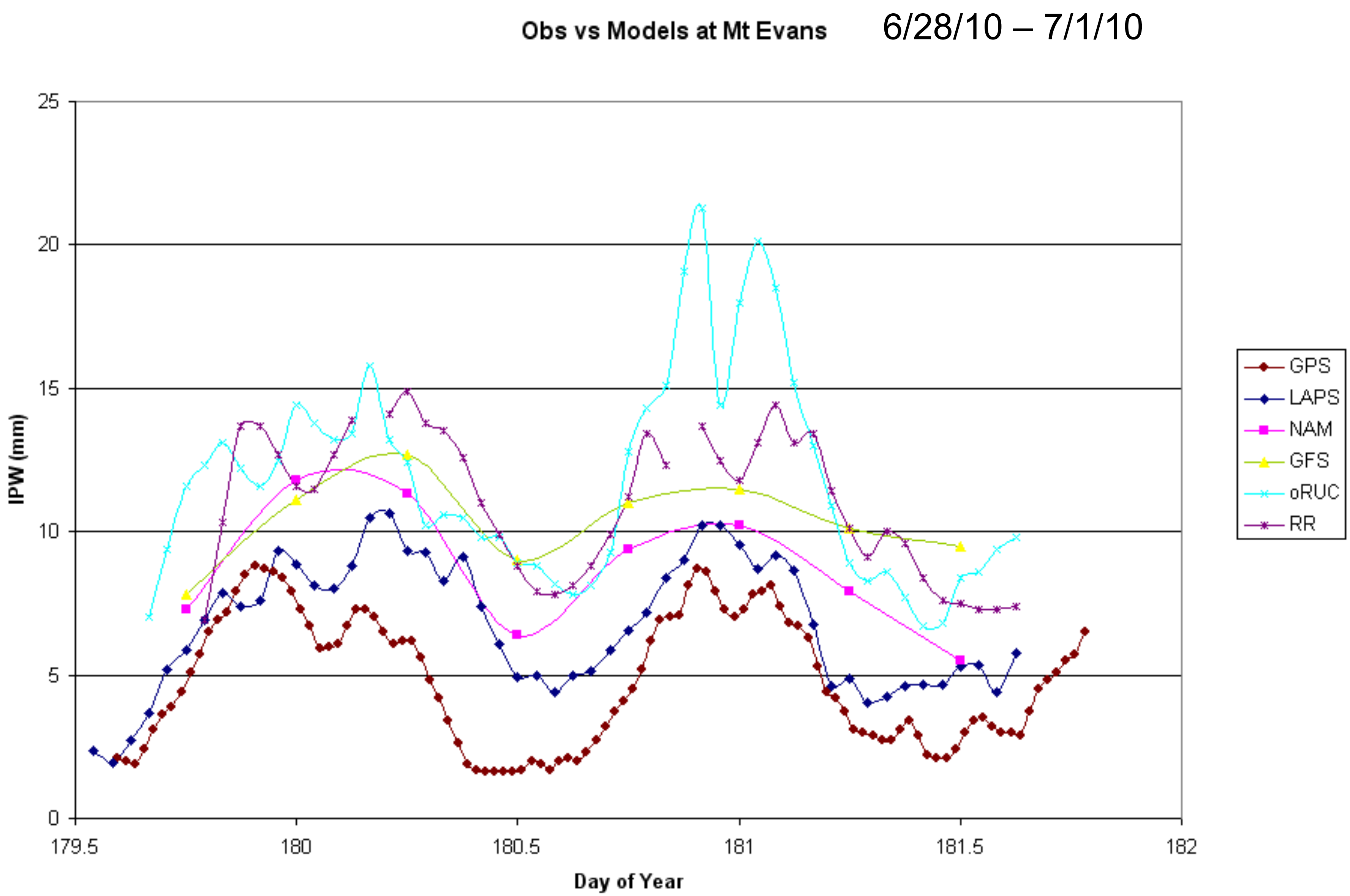
$$+ S_d S_{GVAP} \sum_{j=1}^{3} \frac{\mathrm{G}(g)[\sum_{i=1}^{N} \frac{\Delta}{\Delta y} \mathrm{P}_{ji}(c_i q_i) - \frac{\Delta}{\Delta y} Q_j^{GVAP}]^2}{E_{yGVAP_j}^2 L_{GVAP}}$$

$$+ S_{CLD} \sum_{i=1}^{N} \frac{g_i [c_i q_i - q_s(t_i)]^2}{E_{CLD}^2}$$

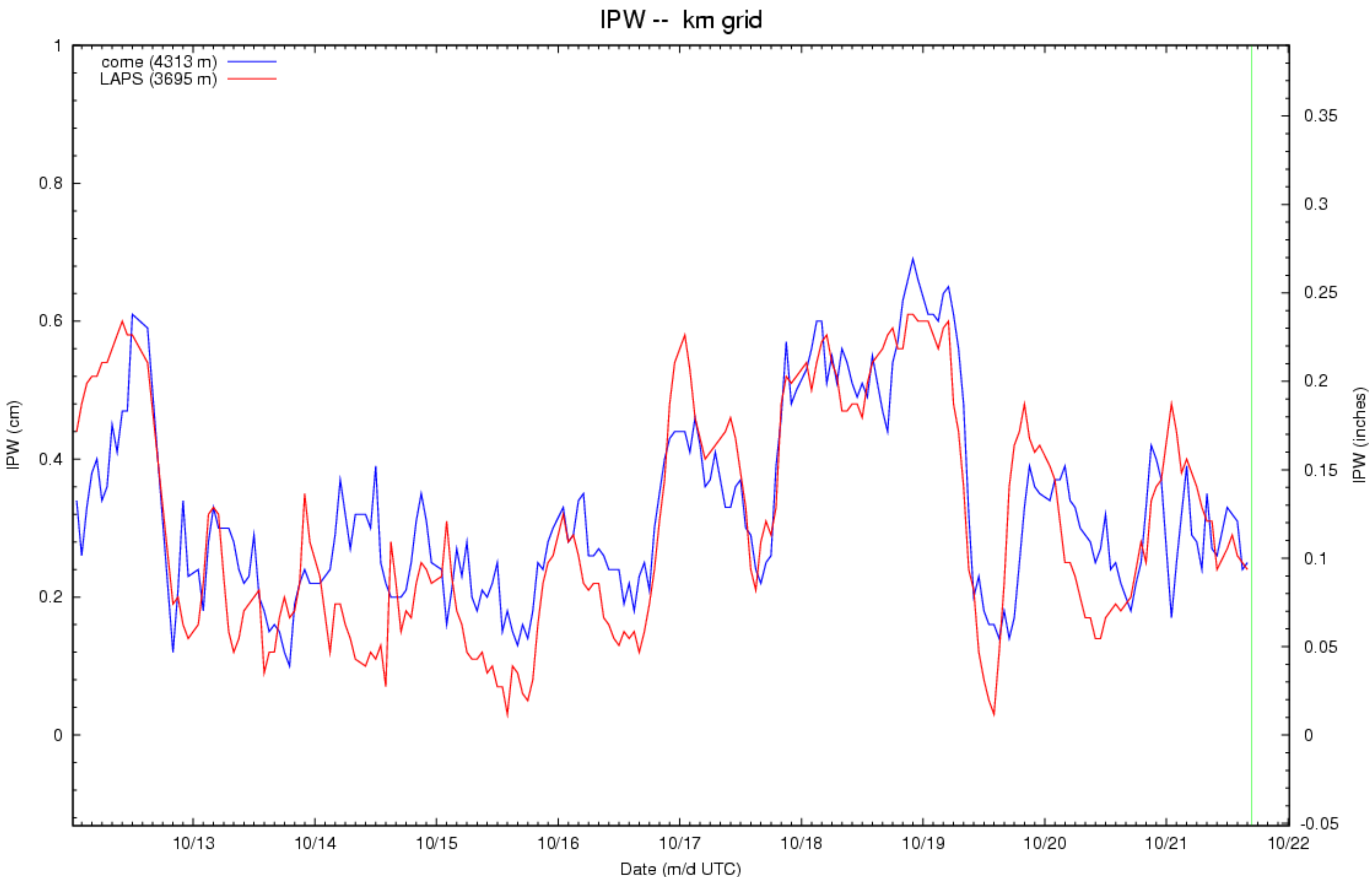
This term becomes gradient in i and j directions.

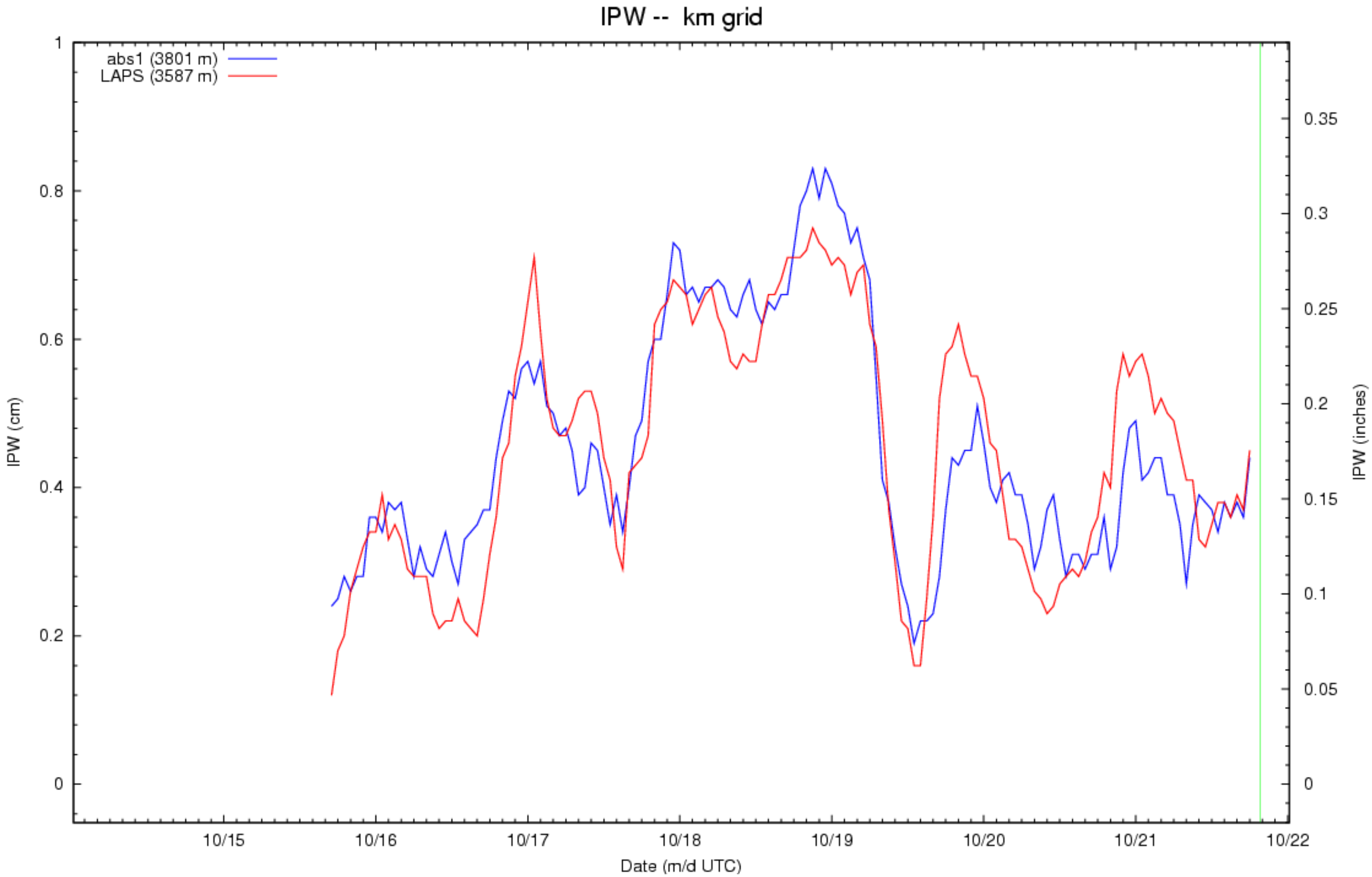

NOAA/FSL LAPS 10km
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
Total Precipitable Water cm
VT 23-May-2005 1300 UTC


NOAA/FSL LAPS 10km
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5
Total Precipitable Water cm
VT 23-May-2005 1300 UTC



Obs vs Models at Mt Evans
6/28/10 – 7/1/10
25
20
15
10
5
0
IPW (mm)
179.5
180
180.5
181
181.5
182
Day of Year
GPS
LAPS
NAM
GFS
oRUC
RR


IPW -- km grid
come (4313 m)
LAPS (3695 m)
IPW (cm)
IPW (inches)
Date (m/d UTC)
1
0.8
0.6
0.4
0.2
0
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
10/13
10/14
10/15
10/16
10/17
10/18
10/19
10/20
10/21
10/22



New GPS comparison with LAPS - A-Basin, another complex terrain location.

Areas of known work relevant to STMAS and a humidity solution

- Cloud relationships in humidification
- Boundary layer and mixing clarification (simultaneous solution)
- LSM = better boundary layer moisture knowledge

Summary

- No question, humidity analysis is tough due to phase changes
- Evapotranspiration is under-addressed
- Surface (bl) moisture mixing remains approximated
- GPS has offered real quantitative constraints that are reliable.
- Satellite gradients eliminate bias errors, research topic on how to formulate this in terms of radiance gradients